On the Determination of the Thermal Diffusion Factor from Column Measurements

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A new method for experimental determination of the thermal diffusion factor $\alpha_T$ for binary gas mixtures with a thermal diffusion column (TDC) is developed, based on A. M. Rozen's equation of TDC. The experimental results for $\alpha_T$ are obtained in a reduced form in this approximation. An experimental reference point, determined in the same TDC with a standard gas mixture, is used for the transformation of the results for $\alpha_T$ in absolute units. The proposed method is applicable for arbitrary gas mixtures, irrespective of the mass difference of the components.

KEY WORDS: gas mixtures; thermal diffusion; thermal diffusion factor.

1. INTRODUCTION

Thermal diffusion (TD) was theoretically predicted by Enskog [1] and Chapman [2] independently in 1911 and 1912. The effect was experimentally confirmed in 1917 by Chapman and Doutson [3] on $\text{H}_2$-$\text{CO}_2$ and $\text{H}_2$-$\text{SO}_2$ mixtures using the two-bulb method. The detailed investigation of this effect was started with the works of Ibbs [4] and other investigators 2 years later. More recently a sufficiently rigorous point of view on the physical aspects of TD was given by Monchik and Mason [5] (see also Ref. 6).

Up to the discovery of the thermal diffusion column (TDC) by Clusius and Dickel [7], TD aroused only academic interest. The remarkable conclusion of Clusius and Dickel, that it is possible to create a continuous mass transfer by the thermal diffusion effect in conjunction with the vertical...

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convection flows, led to the practical use of the TDC for separation of liquid and gas mixtures.

The theory of TDC was developed by Clusius and Dickel [8], Waldmann [9], and Van der Grinten [10]. A more general theory was later proposed by Bardeen [11].

Exact solutions for the TDC with a flat geometry were given by Furry et al. (FJO) [12]. The coaxial cylindrical column, more suitable for practice, was considered by Furry and Jones [13]. In all the former cases very idealized models were used—a Maxwellian gas or a gas of hard spheres, one-component systems, and others. The theories of TDC are reviewed in an elementary, but physically clear way in the article by Jones and Furry [14].

All these early theories are based on the kinetic theory of gases, the kinetic coefficients being obtained from kinetic equations derived in terms of collision cross section and mean free path. The FJO theory was modified by Rutherford and co-workers [15, 16] for the purpose of including the case of the light-isotope mixture separation in TDC with an annular space geometry. Relations, derived in Ref. 16, have been used by this author for obtaining the TD factor $\alpha_T$ of dilute Ne-Xe mixtures in the TDC, the separation process being confined between two vertical, concentric tubes [17]. In more recent papers [18, 19], Rutherford extended his theoretical treatment of the problem, obtaining numerical evaluation for TDC equations under conditions of large temperature differences and when the properties of the gas mixture components strongly depend on the temperature.

On the other hand, Rozen [20] showed that the problem for separation of gas mixtures in a TDC can be considered in the framework of the general phenomenological theory of mass transfer using the concept of transfer unit height (TUH).

2. THERMAL DIFFUSION FACTOR: METHODS FOR ITS DETERMINATION

According to nonequilibrium thermodynamics [21], the overall mass diffusion flow $j_k$ along the coordinate $s$ in an $n$-component system at the absence of any external forces is given by

$$j_k = -\rho \left[ \sum_{j=1}^{n} D_{kj} \frac{\partial x_j}{\partial s} - D_{Tk} \frac{\partial (\ln T)}{\partial s} \right]$$

where $\rho$ is the density of the gas mixture, $x_j$ is the concentration of the corresponding component of the mixture, $D_{Tk}$ is the thermodiffusion